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Background:

The former Baltimore Museum of Art's (BMA) Building Automation System (BAS) — regulating, monitoring, and recording temperature and humidity throughout the Museum building—was in need of replacement, coinciding and syncing with a comprehensive, multi-year renovation at the BMA. The previous system was comprised of a Barber Colman Network 8000 with six host stations, eight global control modules, 64 micro-zone controllers, and 179 micro-flo controllers. The pneumatic controls were installed between 1979 and 1992, the period during which the first mechanical systems designed for precise temperature and humidity control were added to the Museum complex. Digital controls were incorporated into the system in 1994. This hybrid BAS was not effective for the precise environmental control required in the Museum environment, and each of the existing subsystems were highly problematic and programming changes had to be entered manually into each monitoring station, reducing reliability and efficiency. As well, the system was both proprietary and obsolete, and the manufacturer stopped producing replacement parts and writing software updates for the added digital controls.

In 2010, as a part of a study of the current BAS and the schematic design phase for the new system, engineers from Mueller Associates recommended replacing the outdated hybrid pneumatic/digital controls with a modernized digital system. The new BAS would make it easier and more secure to access the system through the internet; make information management on environmental conditions more effective; and foster better communication among HVAC controllers using an industry-standard, non-proprietary protocol.

For the complicated BAS technology required by the BMA and other art museums, there were few options for communication platforms. Engineers identified two—LonWorks and BACnet—both of which would have enabled the different devices and building systems to interact effectively. The BMA selected BACnet after careful consideration of the cost, existing wiring structure, and compatibility to the existing HVAC equipment. For installation of the new system, Mueller Associates sought cost estimates from three vendors and selected Pritchett Controls, having evaluated their products for cost, reliability, and life expectancy, and after consultation with Pritchett engineers regarding how conditions could be maintained during the phased installation of the new system.

Project Activities and Accomplishments:

The NEH-funded Building Automation System (BAS) replaced the previously existing Museum automatic control systems, including the Direct Digital Control (DDC) system. The DDCs replaced throughout the Museum were pneumatic control devices with electronic components and integrated lighting control.

The scope of work was as follows:

- **The electrical control system work** included all electrical and mechanical connections that comprise a complete and fully functional system. This included modifying and extending wiring as required to accommodate site conditions, and adding surge protection components to safeguard control equipment.
- **Mechanical work:** Piping was modified as required to accommodate the existing control valves, including related insulation replacement. Hot water lines were drained and filled, coordinated by Chemstar – a recognized leader in water treatment technology and distributors of the most advanced "green" water treatment products serving the Baltimore-Washington area. Chemstar was the chemical treatment vendor on this project and monitored and evaluated all chemical levels for the new equipment. Installation of new hangers and supports and testing of new piping connections and valves were all completed. Cooling system outages were closely coordinated through the Museum's Facilities Department and with the comprehensive renovation General Contractor, Whiting-Turner.
- **User interfaces:** Accessibility was, and is, accomplished by the standard web browser. All updates to graphics, computer server, trending log, historical data, etc., is located and monitored on the BMA/BAS server.
- **Graphics:** Existing graphics of the previous automated system were replicated for the new system and included drawings of the then system to show access points via Signal software. Because the Museum's Facilities Department staff had become accustomed to the arrangement of items in the existing graphics, the new graphics that were incorporated were designed in similar fashion. The graphics display values and set-points as well as status indicators; they are clickable and used to modify values for temperature and humidly levels throughout the museum. This work also built on the previous graphics, including outside air damper symbols that had been missing from original graphics.
- **Keyboard commands:** The existing keyboard commands were replaced with a web-based graphical interface to interact with the navigation of and shortcuts for the BAS. These new shortcuts were designed to be similar to the original keyboard commands used by Museum Facilities Department staff.

- **Trends**: Pritchett Controls replicated all trend logging and historical data presentation capabilities that the Museum staff had been using with the original software. The new software accommodates date ranges, multi-variable plotting, and correlates and displays derived values such as heating/cooling degree days. Historical logs from the Signal data files of the Global Control Module (GCM) were saved and all unsaved logs were converted to Excel files; these files—Signal data and Excel data—are stored on the original BAS workstation.

- **Alarms:** All existing alarm conditions were replicated in the new BAS, which sends alarm messages to the cell phones of assigned personnel with an additional display and printing of the message at selected user interfaces.

Work Phases:

The foundation of this project began with the replacement of individual GCMs for each existing group controller to the new Enterprise Network Controller (ENC). The following actions were taken to accomplish this preliminary work:

- Mounted new ENC group controller near existing GCM.
- Connected new BAS Bus wiring from server to the new group controller.
- Replaced each GCM Microzone II controller one subsystem at a time:
    - Replicated existing sequences of operation in the new device controller.
    - Mounted new device controller near the existing Microzone II.
    - Ran new BACnet Bus wiring from original group controller or nearest node on group bus to the new device controller.
    - Recorded the accuracy of existing room temperature and humidity sensors for use in the comparison described later in the final commissioning.
    - Reconnected existing wiring from the new device controllers to existing end devices (temperature sensors, valve actuators, and dampers).
    - Transferred existing wiring for associated end devices from the MicroZone II controller to the new device controller.
    - Provided monitoring and logging of points as indicated.
    - Verified communication between group controller and new device controller.
    - Verifed operation of the new device controller.
    - Removed the MicroZone II controller.

Following this initial work, the engineers phased the project to efficiently and responsibly accomplish the BAS replacement with the least amount of impact to the Museum operations and collection.

Phase 1:
ENCs were upgraded for unifying Phase 1, 2, 3, and 4 to one central operators' interface. This laid the groundwork for a seamless transition of the replacement of the older controllers in phases, causing minimal downtime. This included the following:

- Installed Schneider I/A series ENCs for integration to existing Network 8000 Network Controllers. This replaced the GCM 1, 2, 3, 4, 5, 7, and 8 and provided a new Graphical User Interface (GUI).
- Networked cabling to each ENC and the server.
- Installed Enterprise Server Software and one new desktop computer and monitor.

- Moved all existing Signal graphic points into the new Niagara framework.
- Moved and translated the existing global controller programming to be compatible with the new Enterprise network controller programming.
- Moved all of the existing trends, alarms, and schedules to the Niagara Framework.
- Stored all historical data and trends.
- Up-graded the automatic paging and emailing of alarm response data.
- Tested the installation.

Phase 2:
Replaced the existing Network 8000 controllers with Schneider I/A series BACnet controllers associated with GCM 1, 2, and 3. This included the replacement of the associated pneumatic damper and valve actuators with new VAVreheat and cooling valve assemblies through the following:

- Installed new Schneider I/A BACnet Controllers to replace Microzone II controllers.
- Installed new BACnet programming to replace the existing Network 8000 programming and sequences.
- Replaced associated pneumatic actuators for Air Handling Unit (AHU) valves and dampers.
- Installed new Schneider I/A BACnet VAV Controllers for VAV boxes.
- Installed new reheats/cooling valves with DDC actuators for the VAV boxes.

Phase 3:
Replaced the existing Network 8000 controllers with Schneider I/A series BACnet controllers associated with GCM 4, 5, and 7. This included the replacement of the associated pneumatic damper and valve actuators with new VAV reheat and cooling valve assemblies through the following:

- Installed new Schneider I/A BACnet Controllers to replace Microzone II controllers.
- Installed new BACnet programming to replace the existing Network 8000 programming and sequences.
- Installed electronic actuators and new valves for AHU valves and dampers
- Installed electronic actuators for the Turbo Ice Storage Systems and Cooling Tower.
- Installed new Schneider I/A BACnet VAV Controllers for VAV boxes.
- Installed new reheats/cooling valves with electric actuators for the VAV boxes.

Phase 4: West Wing
Replaced the existing Network 8000 controllers with Schneider I/A series BACnet controllers associated with GCM 8. This included the replacement of the associated pneumatic damper and valve actuators with new VAV reheat and cooling valve assemblies through the following:

- Installed new Schneider I/A BACnet Controllers to replace Microzone II controllers
- Installed new BACnet programming to replace the existing Network 8000 programming and sequences
- Replaced associated pneumatic actuators for Air Handling Unit (AHU) valves and dampers.
- Installed new Schneider I/A BACnet VAV Controllers for VAV boxes.

Change existing VAV

The VAV box controllers (Barber Colman MicroFlo II) associated with the GCM needed to be converted to BACnet controllers. The VAV box controllers were replaced during a two day period (a Monday Tuesday sequence) when the museum was closed to the public to allow running temporary Network 8000 outages.

Important to Note:

1. The new GCMs have control functions that continue to operate regardless of network status, including:
   - Global communications.
   - Pass word protection.
   - Discrete\digital, analog, and pulse input\output.
   - Monitoring, controlling, or addressing data points.
   - Testing and developing control algorithms without disrupting field hardware and controlled environment.
   - Control processes.
   - Energy management applications.
   - Alarm management.
   - Historical\trend data for points.
   - Maintenance support applications.
   - Custom processes.
   - Dial up communications.
   - Manual override monitoring.

2. **ENC** group control also included the integration of Museum gallery lighting through linking the Lutron Lighting Controls and Power Link Panels with the new BAS. ENCs also monitor and control the BMA emergency generator used for general operation when a power outage or energy curtailment request from the local energy company occur.

Commissioning

Commissioning was performed by Pritchett Controls engineers throughout the project to check, inspect, and test every operational component of the project. Engineers:

- Verified that all changes in condition at each sensor are accurately and responsively displayed on the graphics screen where the point is monitored and recorded in all associated trend logs to initiate an appropriate alarm condition should the condition warrant such, and that historical logs are created and maintained.
- Verified that loss of communication with any controller or end device results in the appropriate alarm and fail safe condition.
- Verified that all operator commands via keyboard or a clickable graphic result in the intended action at the proper point in the system. All controllable points were cycled through their entire ranges of operation via a wireless web browser and confirmed by direct observation that the intended action took place.

On- site training by the Pritchett Controls project engineers occurred over the course of the BAS replacement project, familiarizing the BMA Facilities Department staff with all of the capabilities and functionality of the new BAS system.

Evaluation

This project will be evaluated as an integral part of the comprehensive, 5-year Museum renovation upon its completion. In the interim, all parts and functionality are being tested by the engineering subcontractor hired for this project, Pritchett Controls.

Continuation of the Project

This project was a straightforward, standalone project that complements the BMA's commitment to energy sustainable solutions where possible and careful collection stewardship.

Long Term Impact

The BMA's Building Automation System was designed to centralize control of the Museum's heating, ventilation, and air conditioning, and integrate lighting control. It has improved environmental conditions for the Museum's collection while maintaining temperature and air flow for the comfort of Museum staff and visitors. With this efficient system, both energy consumption and, therefore, operating costs have been reduced. The system's software alarm communication feature allows for rapid response to any Museum HVAC error. This project was an enhancement to the Museum facilities and systemic management through engineering designed to accommodate and expand with any future building projects and changes. This project culminated a 20-year period at the BMA of continuous attention to economy and sustainability in energy management and procurement, as well as to the improvement and maintenance of systems that preserve the Museum's renowned 95,000 works collection.